BROOKLYN STREETCAR

FEASIBILITY STUDY

ALIGNMENT EVALUATION METHODOLOGY TECHNICAL MEMORANDUM

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1.0 INTRODUCTION

This Technical Memorandum outlines the Brooklyn Streetcar Feasibility Study's alignment evaluation methodology. It also presents key technical considerations that will help determine the feasibility of each alignment option to be evaluated as the study moves forward. Goals and objectives were developed at the earliest stage of the study to help guide alignment selection. These are also presented in this document. A number of potential alignments were identified and through the initial evaluation process these were refined and reduced to one potential alignment with various options.

A more detailed evaluation of these options employs a rating scale that considers the degree to which each alignment option satisfies the study's defined goals and objectives. The results of this ranking will be included in the forthcoming Feasibility Report.

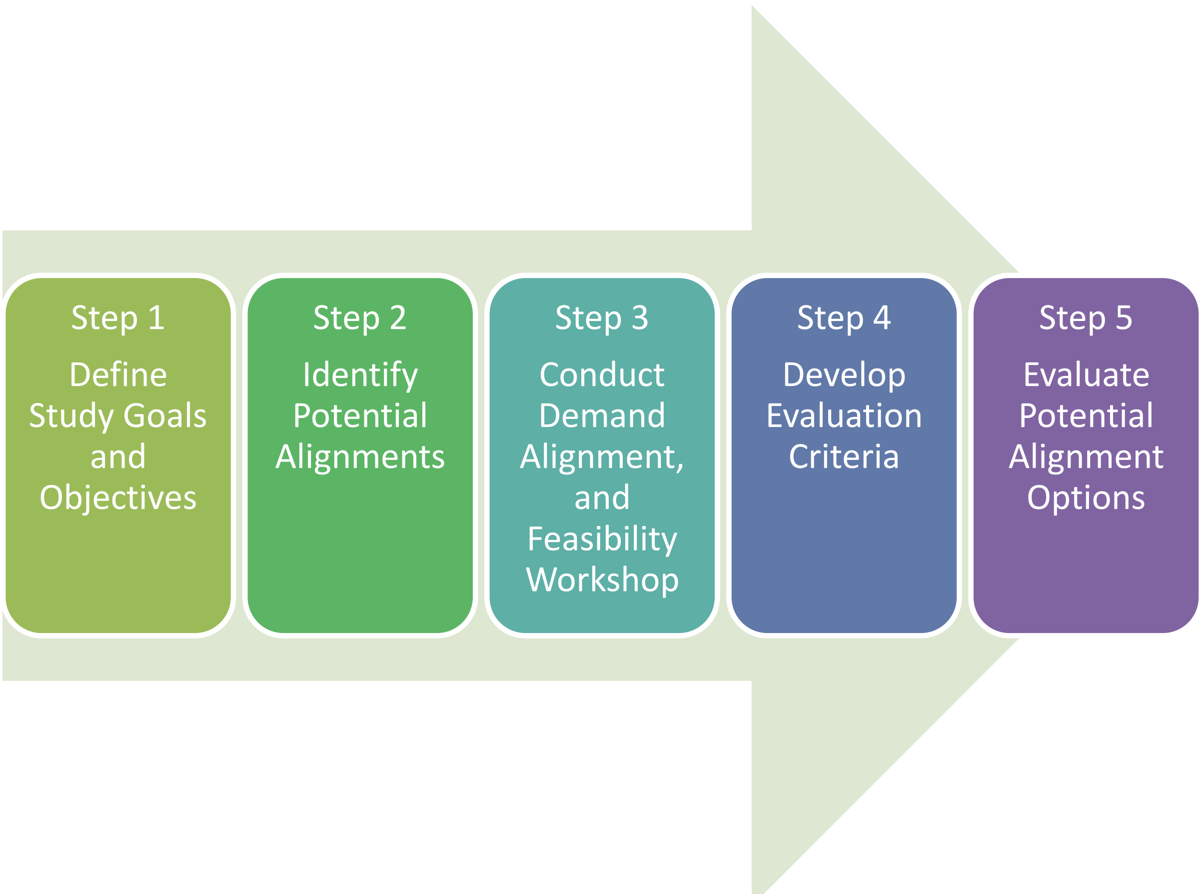
In addition to establishing how the alignment options will be evaluated, this memo presents a number of technical considerations that could affect how viable each option is. Specific areas of concern were identified using the following feasibility considerations:

- Horizontal alignment and curvature
- Grades
- Station platforms
- Vertical clearance
- Roadway cross slopes
- Right-of-way
- Structural operations
- Traffic operation / signals
- Bicycle integration
- Utilities
- Track structure / pavement reconstruction

2.0 ALIGNMENT SELECTION AND EVALUATION METHODOLOGY

This section of the Alignment Evaluation Methodology and Feasibility Considerations Memorandum outlines the process used for selecting and evaluating potential alignments for a streetcar system in Brooklyn. This process includes defining the study's goals and objectives, identifying potential streetcar alignments, developing evaluation criteria, and evaluating and ranking various alignment options. This multi-step process is graphically shown in Figure 2-1, and described in further detail below and throughout this section.

Figure 2-1: Alignment Selection and Evaluation Process



In Step 1, study goals and objectives were discussed and developed during the initial study meetings. In Step 2, alignments were identified based on a number of factors, including land uses that generate significant person trips, employment densities that concentrate these trip generating uses, existing transit that allows for citywide access, and input from the Community Advisory Committee.

In Step 3, additional streetcar alignments were identified and reviewed during a Demand, Alignment, and Feasibility Workshop attended by the New York City Department of Transportation

(NYCDOT) and members of the consultant team. Based on the input received at this workshop and considering planning factors such as existing land use, employment density, existing transit, and the roadway network, the alignments were refined to include one potential alignment with various alternative options. This potential alignment with options was presented at the second Community Advisory Committee (CAC) meeting on December 13, 2010 for validation and additional input.

Using the goals and objectives defined in Step 1, evaluation criteria were developed in Step 4 to assess how well the alignment options address the defined goals and objectives. Step 5 considers the degree to which each alignment option satisfies the defined goals and objectives using a rating scale for the developed evaluation criteria. The rating scale will be used to identify high performing to low-performing options. Each alignment option will be assigned a point value based on where it falls in the spectrum (high to low), and the points for all of the evaluation criteria will be summed to come up with a final point total for each alignment option. The alignment options will then be ranked to determine the alignment that best meets the defined goals and objectives.

2.1 Brooklyn Streetcar Goals and Objectives

Goals and objectives for the Brooklyn Streetcar Feasibility Study were developed at the earliest meetings and further refined as the study progressed. Factors that informed this process include the existing conditions in the Focus and Study Areas, the examples provided in the Case Study Report (Portland, Seattle, and Philadelphia), and input from the CAC.
These Brooklyn Streetcar goals and objectives are shown in Table 2-1.

Table 2-1:
Brooklyn Streetcar Goals and Objectives

GOAL	OBJECTIVE
Improve transportation mobility	✓ Transit accessibility ✓ Travel time ✓ Intermodal connectivity ✓ Enhance pedestrian movements ✓ Accommodate bikeways
Provide economic opportunity and investment and enhance the community character	✓ Serves existing and planned development ✓ Serves developable and re-developable land ✓ Neighborhood resident sentiments ✓ Local business community sentiments
Maintain traffic and delivery access	✓ Maintain delivery access to local businesses ✓ Maintain access to Red Hook's arterial roadways and Brooklyn highways

Table 2-1:
Brooklyn Streetcar Goals and Objectives

GOAL	OBJECTIVE
Minimize adverse impacts on the built and natural environment	✓ Minimize adverse impacts on historical resources ✓ Minimize property acquisition ✓ Minimize construction impacts ✓ Minimize impacts to natural features/resources and coastal waters ✓ Minimize traffic impacts ✓ Minimize noise and vibration impacts
Minimize streetcar capital and operating costs and impacts	✓ Implement within a reasonable construction timeframe ✓ Implement within a reasonable construction cost ✓ Avoid conflicts with existing and proposed infrastructure during construction and operation ✓ Avoid or minimize utility relocation

2.2 Selection of Potential Streetcar Alignments

The key factors that guided the identification of potential streetcar alignments included land uses that generate significant person trips, employment densities that concentrate these trip generating uses, existing transit, and input from the stakeholders and agencies through the CAC. Each of these are described below in greater detail.

LAND USE

The primary reason for considering land use when identifying alignments is the potential each land use has for generating ridership for a new streetcar system. This relationship also works in reverse: the specific transportation mode, such as the streetcar, can impact the development and growth of specific land uses, such as residential and commercial uses. This is particularly evident when transit supportive zoning and land use policies are in place. As shown in Figure 2-2 and reported in the Existing Conditions Report, the Focus Area is defined primarily by industrial and manufacturing uses along the waterfront. This type of land use is typically not a strong generator of ridership for streetcar systems, as these uses tend to have low population and employment densities. The City of New York's policy is to reinforce its industrial and manufacturing zoning along the Red Hook waterfront area, particularly as this type of land use is considered to be increasingly scarce throughout the five boroughs.

The interior of the Focus Area is mostly residential, including the Red Hook Houses, the Focus Area's largest residential land use. The primary commercial corridor runs along Van Brunt Street and along the southern waterfront area where major new retailers IKEA and Fairway have recently opened. It is expected that a future streetcar alignment would improve mobility to and within Red Hook and could be advantageous to the Focus Area's primary commercial and residential corridors. These areas offer the greatest potential for a future streetcar system, based on the experience of other cities, as demonstrated in the Case Study Report.

EMPLOYMENT DENSITY

Figure 2-3 shows the geographic distribution of residential population and employment densities within the Focus Area and the Study Area, based on data from the U.S. Census Bureau (2000), which was the most recent data available. Residents are more closely concentrated on interior blocks with fewer people living along the waterfront. However, recently-completed development and proposed developments in DUMBO, Vinegar Hill, and the Columbia Street Waterfront are anticipated to increase the population density of those waterfront neighborhoods.

Also based on 2000 Census data, the Focus Area is approximately 0.87 square miles with an employment density of approximately 6,274 employees per square mile. The overall Study Area is approximately 2.93 square miles and is significantly denser in employment. The Study Area had approximately 49,072 employees per square mile.

As shown in Figure 2-3, Downtown Brooklyn has a concentrated employment density. This was an important factor when considering future streetcar alignments. Assuming potential streetcar riders would use the streetcar as a travel mode to and from work, the streetcar alignment should connect to Downtown Brooklyn to service the employment center.

EXISTING TRANSIT

Figure 2-4 shows the subway and bus routes that traverse the Focus Area and Study Area. Transit coverage in the Study Area varies greatly from north to south. North of Atlantic Avenue, several bus and subway routes converge, forming a transit hub at Borough Hall. To the south, fewer buses and only two subway lines serve the area, with no subway service within the Focus Area.

As reported in the Existing Conditions Report, the Study Area (outside the Focus Area) is generally well served by public transportation. Eleven subway routes cross into Brooklyn from Manhattan between Jay Street and Joralemon Streets in Downtown Brooklyn, and the G train crosses Downtown Brooklyn on its route connecting to Queens. Most of these subway routes continue easterly or southeasterly from Downtown Brooklyn and exit the Study Area. However, the F and G trains continue southward to serve Cobble Hill and Carroll Gardens.

The F and G subway station at Smith-9th Street is the closest stop to the Focus Area, but accessing the Smith-9th Street Station from Red Hook requires a bus ride or a lengthy and circuitous walk. In addition to subway service, there is one bus route that traverses the Focus Area. The B61 serves Red Hook along Columbia and Van Brunt Streets. The Focus Area is generally poorly served by transit, even though many of its residents rely on public transportation. Recent growth in residential and worker populations has increased the need for transit accessibility.

Figure 2-2: Land Use

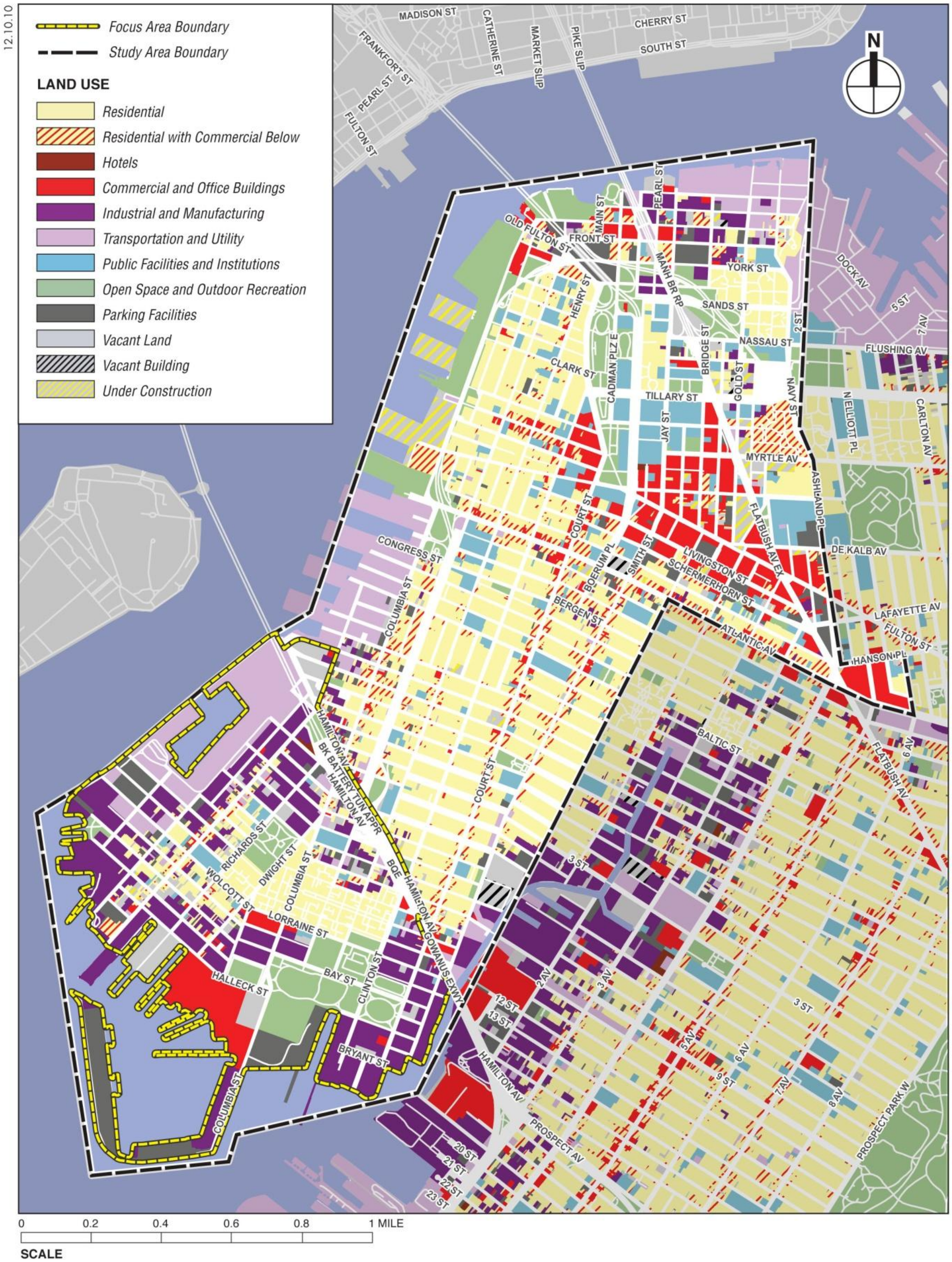
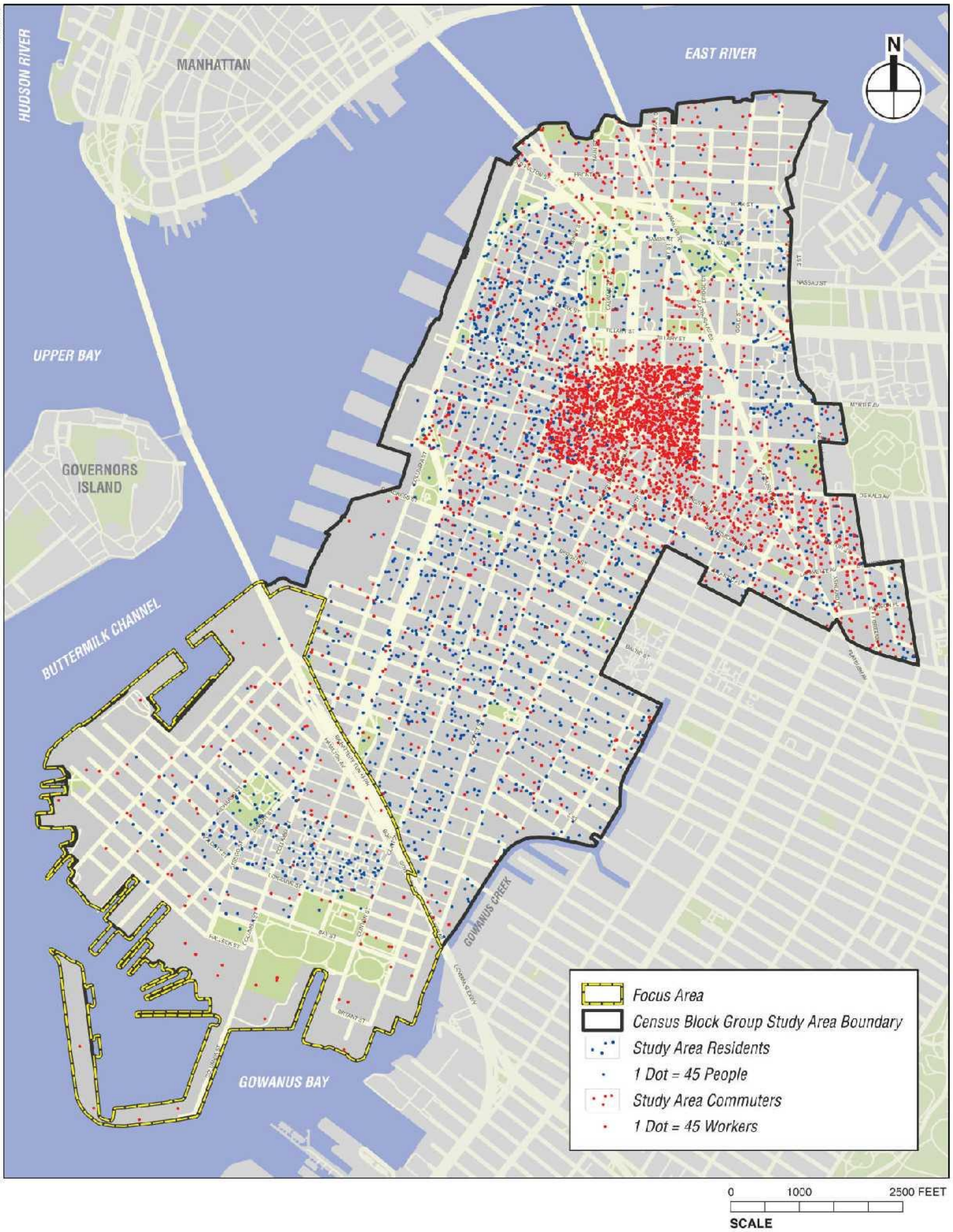
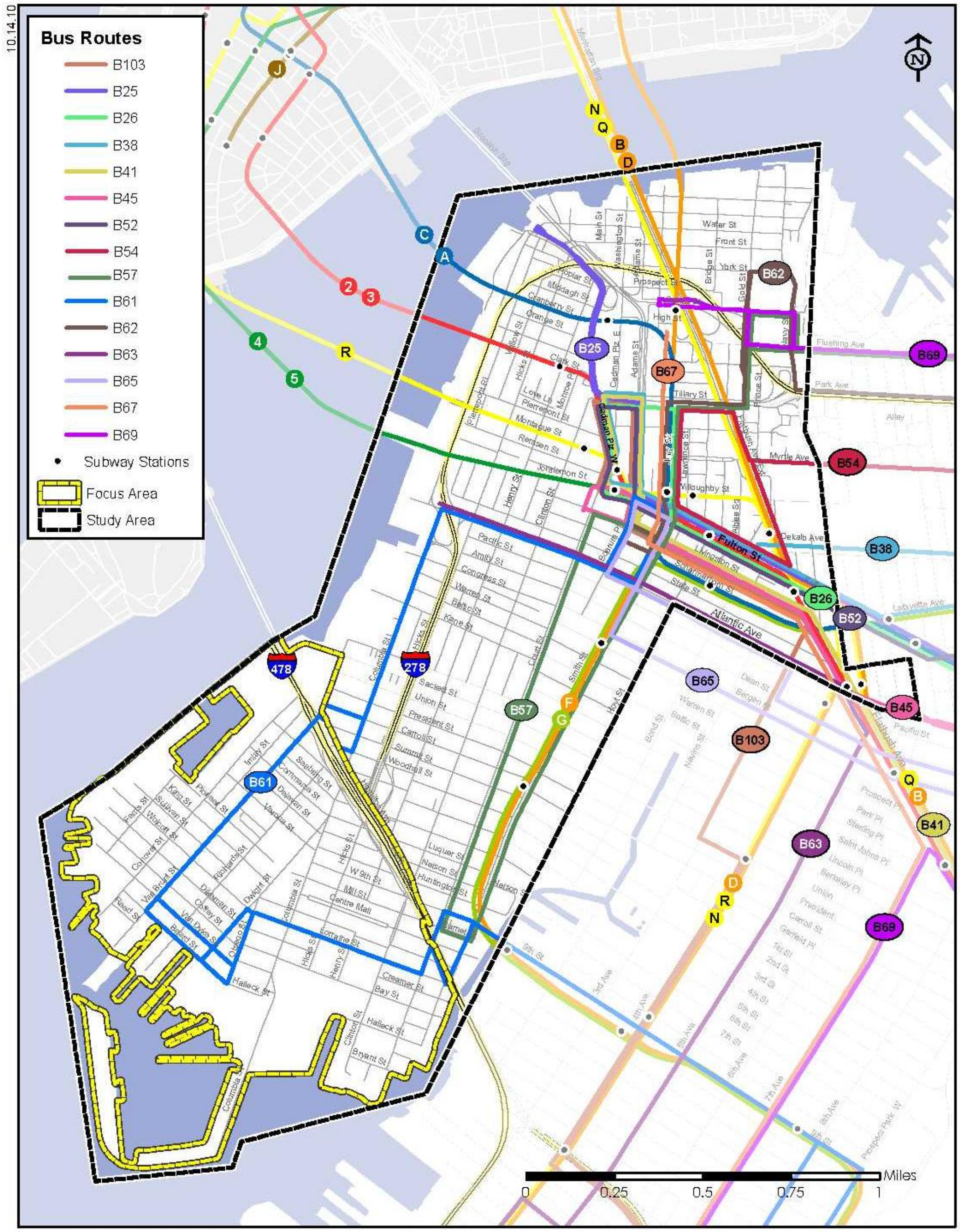


Figure 2-3: Population and Employment Density



Population and Employment Density

Figure 2-4: Existing Transit



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Existing and Subway and Bus Service

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COMMUNITY ADVISORY COMMITTEE

The NYCDOT invited representatives from various public agencies and non-profit interest groups to form a CAC to support the Brooklyn Streetcar Feasibility Study. The CAC first met on October 18, 2010.

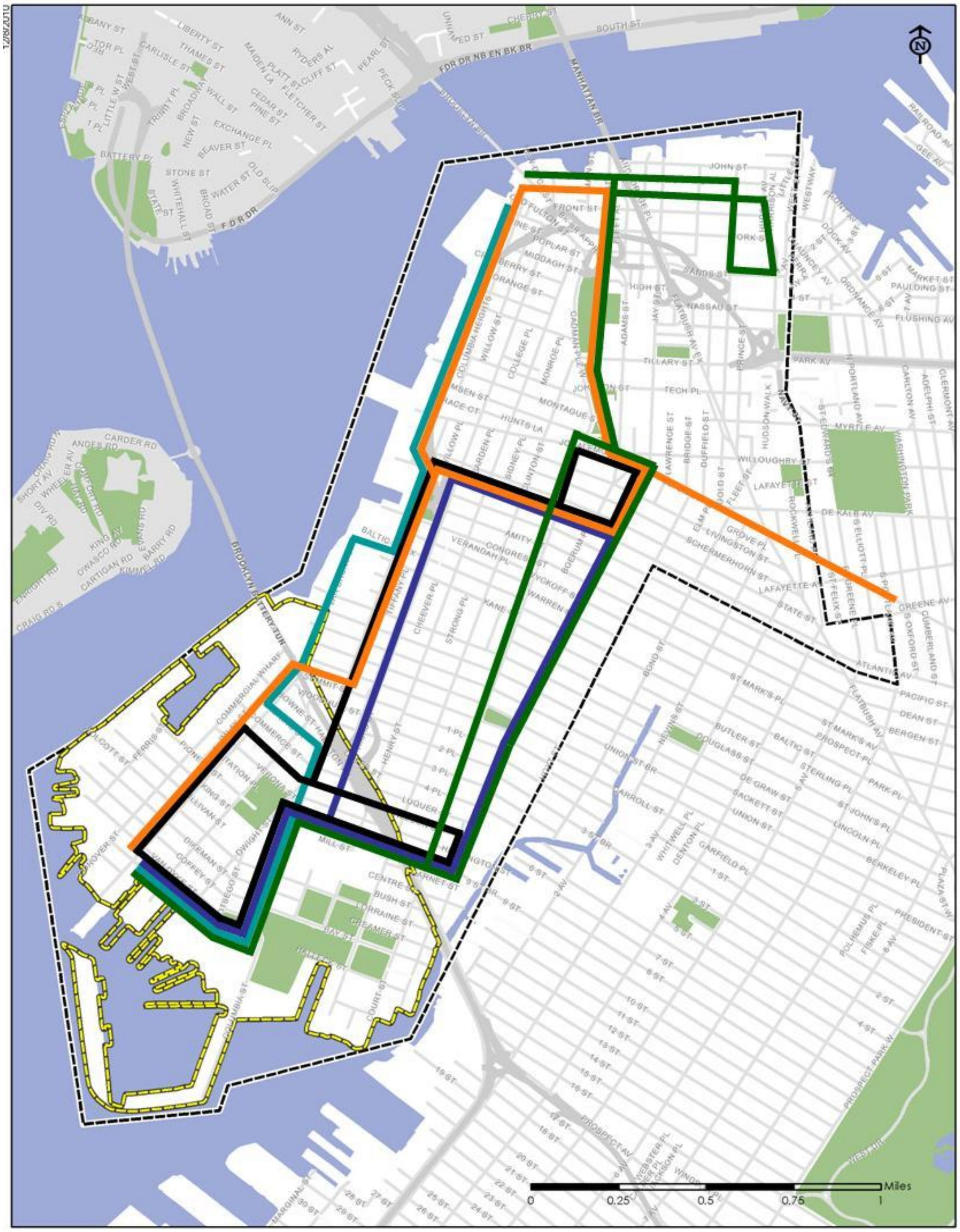
Following the initial CAC meeting, the CAC members were invited to participate in identifying potential streetcar alignments using an online mapping tool. Figure 2-5 presents the results of the online mapping tool. All alignments utilized either Columbia Street or Van Brunt Street within the Focus Area to connect Beard Street with the Study Area. From there the suggested alignments, utilized either the Columbia Street corridor or the Smith Street / Court Street corridor to travel north towards downtown Brooklyn. In downtown, most alignments terminate at one of three terminal points Borough Hall, Brooklyn Bridge Park, or DUMBO.

One CAC member asked if the abandoned rail tunnel under Atlantic Avenue or the route over the Brooklyn-Queens Expressway were considered. The study team considered this alignment; however, both of these routes would require a significantly higher capital investment and are not consistent with desired streetcar characteristics (pedestrian friendly, street-level service). Another attendee asked if the number of employees at the Red Hook Marine Terminal was considered and whether travel between various terminal sites were factored into the ridership estimate. The NYCDOT indicated all Red Hook employee trips were considered, and the potential alignment is an attempt to capture both port and commercial areas.

HISTORICAL ROUTES

The study team also looked at historic streetcar routes in Brooklyn. This was informative from the standpoint of showing the breadth of streetcar operations that once extended throughout Brooklyn. Several streetcar lines ran through Red Hook from 1893 through 1949, when Brooklyn's streetcar lines were converted to bus routes, with the Borough's last streetcar ceasing operation in 1956. These routes are shown in Figure 2-6. The Furman Street, Erie Basin, and Crosstown Lines ran along Columbia Street, and the Hamilton Avenue Line ran between Red Hook and Bay Ridge. Although these streetcar lines at one time successfully provided transit service in Brooklyn, land uses and other conditions have significantly changed since these historic routes were in service. Therefore, these lines did not influence the alignment selection process.

Figure 2-5: Community Advisory Committee Alignments



Van Brunt and Columbia Streets
Van Brunt, Columbia, and Fulton Streets
Hicks and Smith Streets
Court and Smith Streets

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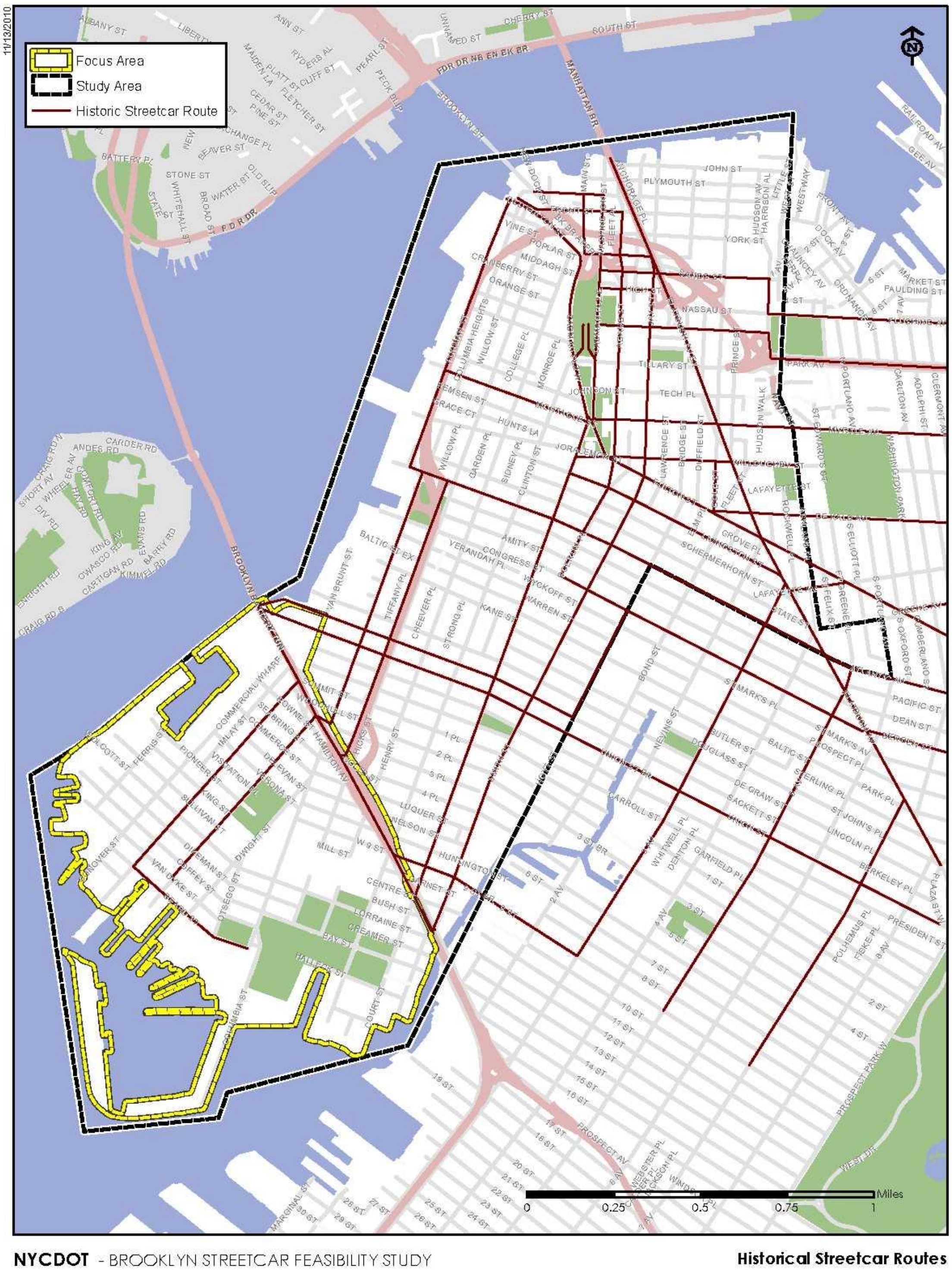
Figure 2-6: Historical Streetcar Routes



2.3 Demand, Alignment, and Feasibility Workshop

A Demand, Alignment, and Feasibility Workshop was held on November 15, 2010 to discuss the potential streetcar alignments that were initially identified based on land use, population and employment density, existing transit, and input from the CAC. The workshop included representatives from the NYCDOT and the consultant team. Based on the workshop discussions, the list of potential alignments was narrowed to one primary alignment with a number of options that will be further evaluated as the study progressed. Alignments that were removed from current consideration, and the reason they were removed are listed in Table 2-2.

Table 2-2:
Alignments Removed from Consideration

ALIGNMENT	SOURCE	REASON REMOVED
Court Street or Smith Street, from Focus Area to Atlantic Avenue	CAC	Proximity to the F and G subway lines
Clinton Street or Henry Street, from Focus Area to Atlantic Avenue	NYCDOT / Consultant Team	Exclusively residential land uses Limited right-of-way
Hicks Street, from Focus Area to Atlantic Avenue	CAC	Major infrastructure obstacles (Proximity to Interstate 278), Exclusively residential land uses
Furman Street, from Atlantic Avenue to DUMBO (along Brooklyn Bridge Park)	CAC	No connection to transit hub
Carroll Street and Summit Street, 1st Place from Van Brunt Street to Smith Street	NYCDOT / Consultant Team	No connection to transit hub

Specifically, the following factors were discussed:

Land Use

The focus of the Brooklyn Streetcar Feasibility Study is to study the feasibility of a streetcar in Red Hook and to provide service for Red Hook residents and visitors. Therefore, any alignment that would not serve the interior residential land uses within the Focus Area was eliminated. As previously mentioned, the Red Hook Houses is the largest residential land use in the Focus Area. As such, a future streetcar should provide service to this land use.

Similarly, Red Hook's primary commercial corridor running along Van Brunt Street and the southern waterfront area (along Columbia Street) where major new retailers have recently opened offer strong potential for a future streetcar system. The alignments along Clinton Street and Henry Street were eliminated, as they do not have the commercial-advantage as does Van Brunt Street and Columbia Street.

Employment Density

Downtown Brooklyn is New York City's third largest central business district (CBD) after Midtown and Downtown Manhattan. Downtown Brooklyn serves as a government center, with city, state, and Federal institutions. As reported in the Existing Conditions Report, approximately 11 percent of Focus Area residents commute to Downtown Brooklyn. Another 15 percent of residents work in the Focus Area. Therefore, a future streetcar service providing better connectivity within the Focus Area, as well as to Downtown Brooklyn has the potential to serve up to 26 percent of the Focus Area. To serve this employment market, connection to Downtown Brooklyn will be included as an option.

Existing Transit

The F and G subway station at Smith-9th Street is the closest stop to the Focus Area, but accessing the Smith-9th Street Station from Red Hook requires a bus ride or a lengthy and circuitous walk. The addition of a streetcar line would improve transit accessibility for the Focus Area. In addition, connection to the Atlantic Avenue Station with the B, Q, 2, 3, 4, and 5 subway lines, the Pacific Street Station with the D, M, N, and R subway lines, and the Jay Street-Borough Hall Station with the A, C, and F subway lines would improve overall transit access and circulation. As such, connection to all three of these subway stops will be included as an option, as an alignment that provides intermodal connections would further enhance the effectiveness of transit service in the area. For this reason the alignments along Furman Street and Carroll Street were eliminated, as these alignments would not provide a connection to a major transit hub. These alignments, however, could be part of future extensions to the initial streetcar system.

Existing transit service was also considered in order to meet the needs of underserved areas and avoid redundancy with existing fixed-guideway rail service (subway). The Focus Area is poorly served by transit, even though many of its residents rely on public transportation. A future streetcar system would help improve mobility to and within Red Hook. Similarly, Smith and Court Street are served by existing subway service, and the alignments along these corridors would provide redundant service. In an effort to provide better transit accessibility throughout Red Hook and meet the needs of underserved areas, the alignments along Court and Smith Streets were eliminated for this feasibility study.

Roadway Network

Interstate 278 (I-278), a major east-west highway that runs from New Jersey to the Bronx via Staten Island, Brooklyn, and Queens runs along Red Hook's eastern and northern edges within the Focus Area. From the Verrazano Narrows Bridge, I-278 constitutes the Gowanus Expressway, a single-level six-lane freeway, widening to eight lanes before the Brooklyn Battery Tunnel, which runs under the East River and connects Brooklyn and Manhattan. Entrances to the Brooklyn Battery Tunnel are situated at Red Hook's northern edge.

As reported in the Existing Conditions Report, these transportation facilities established *de-facto* neighborhood borders for Red Hook by cutting it off physically and socially from adjacent neighborhoods. In terms of planning for a future streetcar line, the location of both I-278 and the Brooklyn Battery Tunnel are important in terms of the constructability of a streetcar line crossing these facilities. Specifically, the Hicks Street alignment was eliminated due to its proximity to I-278. Similarly, based on preliminary investigation, Columbia Street would provide the most feasible option for crossing I-278.

POTENTIAL STREETCAR ALIGNMENT FOCUS AREA OPTIONS

As a result of the Demand, Alignment, and Feasibility Workshop, one potential alignment was identified with a number of options, as shown in Figure 2-7. In the future, with more data and more detailed site investigations, as well as further public input, additional alignments could also be considered if the study continues into a Federal Transit Administration (FTA) Alternatives Analysis (pending the outcome of this feasibility study).

As shown in Figure 2-7, the potential streetcar alignment travels along Beard Street in the southern most segment of the alignment. For the Focus Area East, the potential alignment has two options: traveling in both directions on either Centre Street or Lorraine Street. For the Focus Area West, the alignment also has two options: traveling in both directions on Van Brunt Street or traveling northbound on Richards Street and southbound on Van Brunt Street. For the Middle Section of the potential alignment, three options are available connecting Van Brunt Street to Columbia Street, and for the Northern Section, the potential alignment either travels further east and terminates on Atlantic Avenue, or terminates at Borough Hall with a dead end or loop track.

These alignment options parallel the ideas presented by the CAC. The alignment options serve the commercial corridors of Beard Street and Van Brunt Street similar to the suggested alignments shown in Figure 2-5. In addition, the alignment options connect the Focus Area to downtown Brooklyn and existing transit services at Borough Hall or Atlantic Terminal.

2.4 Evaluation Criteria

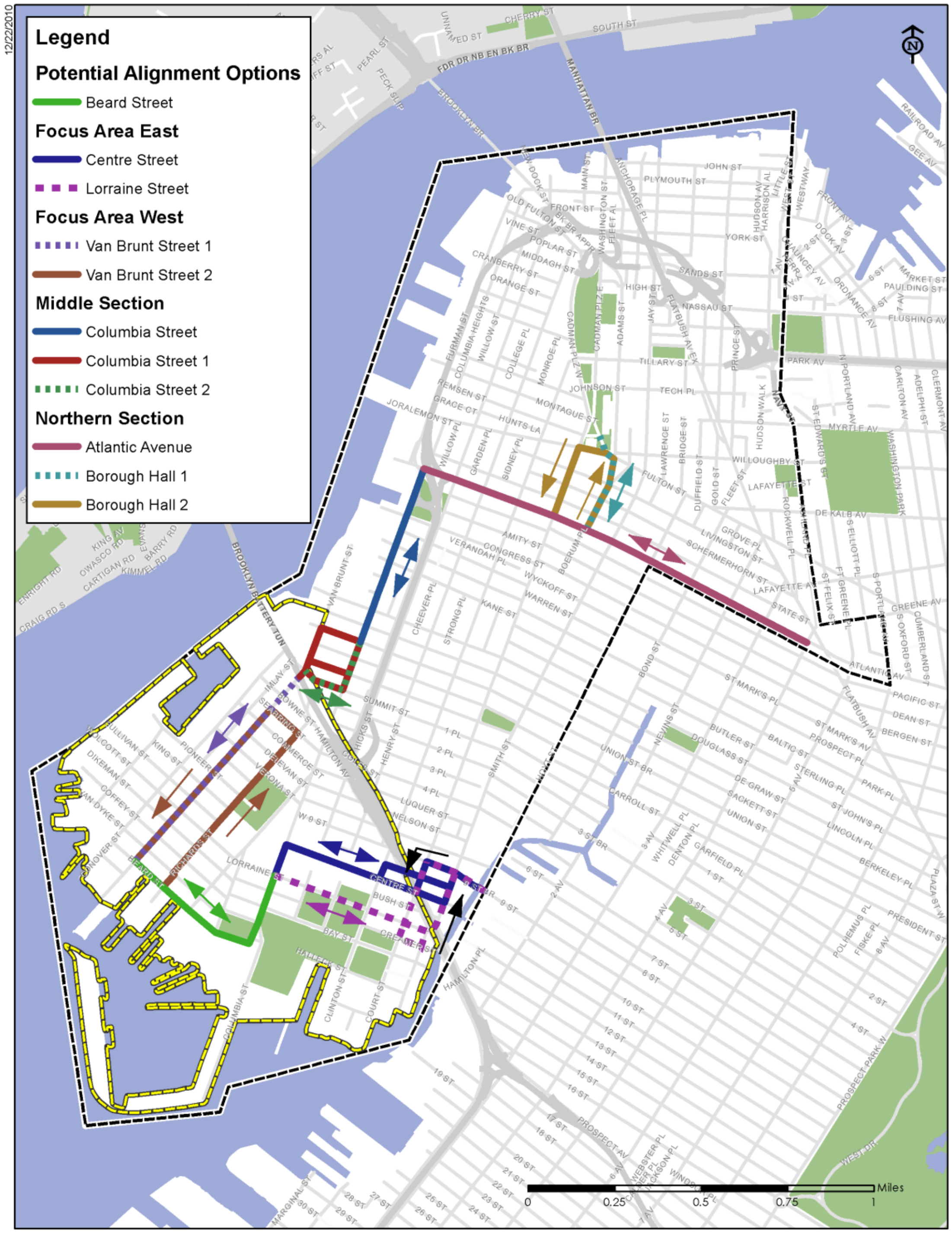
Evaluation criteria were developed to help assess how well each alignment option meets the study's Goals and Objectives, shown in Table 2-1. While these measures are generally qualitative, they allow for a comparison of the order of magnitude benefits and detriments of each alignment option. This method also provides a means to compare options to each other to identify the best solution. Table 2-3 includes the streetcar goals and objectives and the corresponding evaluation criteria for the forthcoming evaluation of the streetcar alignment options.

Each alignment option will be assessed based on the goals and objectives identified in Table 2-2 using the evaluation criteria identified in Table 2-3. This evaluation will consider the degree each alignment option satisfies the goals and objectives based on the respective evaluation criteria. To do this, a rating scale, ranging from high performing to low-performing scores, is used. This rating scale is shown below. Point values are assigned for the respective ratings of each performance measure identified in Table 2-3. Below is the point system that is designated for the respective performance measures.

High performing	●	◕	◑	◔	○	*Low performing*
	20	*15*	*10*	*5*	*0*	

The points for all the performance measures are added to come up with a final point total for each alignment option. The alignment options are then ranked to determine the alignment(s) that best meet(s) the defined goals and objectives.

Figure 2-7: Potential Alignment Options



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Potential Alignment Options

**Table 2-3:
Brooklyn Streetcar Evaluation Criteria**

GOAL/OBJECTIVE	EVALUATION CRITERIA
IMPROVE TRANSPORTATION MOBILITY	
Transit accessibility	– Population within 1/3–mile of streetcar stops – Employment within 1/3–mile of streetcar stops – Activity centers within 1/3-mile of streetcar stops
Travel time	– Trip time savings to and from various trip-generators, compared to existing bus service
Intermodal connectivity	– Provides bus connections – Provides subway connections
Enhance pedestrian movements	– Minimizes interference with pedestrian movements – Improve pedestrian space
Accommodate bikeways	– Minimizes interference with existing/planned bikeways – Minimizes impacts to bicyclist safety – Minimizes conflicts with proposed Greenway alignments
PROVIDE ECONOMIC OPPORTUNITY AND INVESTMENT AND ENHANCE THE COMMUNITY CHARACTER	
Serves proposed/projected development	– Estimated population within 1/3–mile of streetcar stops – Estimated employment within 1/3–mile of streetcar stops – Proposed activity centers within 1/3-mile of streetcar stops – Minimizes vehicle restrictions to access Red Hook's Arterial roadways and Brooklyn highways – Minimizes changes to parking supply – Minimizes changes to delivery access

Table 2-3:
Brooklyn Streetcar Evaluation Criteria

GOAL/OBJECTIVE	EVALUATION CRITERIA
Serves developable and re-developable land	– Access to proposed streetcar stops
Neighborhood resident sentiments	– Amount of streetcar support/opposition
Local business community sentiments	– Amount of streetcar support/opposition
MAINTAIN TRAFFIC AND DELIVERY ACCESS	
Maintain curb access	– Change in curb access (linear feet)
Maintain access to Red Hook's arterial roadways and Brooklyn highways	– Minimizes vehicle restrictions to access Red Hook's arterial roadways and Brooklyn highways – Maintain truck access to local and through truck routes
MINIMIZE ADVERSE IMPACTS ON THE BUILT AND NATURAL ENVIRONMENT	
Minimize adverse impacts on historical resources	– Minimizes visual impacts to historic resources – Minimizes historic property acquisition
Minimize property acquisition	– Minimizes property acquisition
Minimize construction impacts	– Shorter construction duration
Minimize impacts to natural features/resources and coastal waters	– Minimizes interference with parkland or coastal waters
Minimize traffic impacts	– Minimizes negative impact on traffic flow
MINIMIZE STREETCAR CAPITAL AND OPERATING COSTS AND IMPACT	
Implement within a reasonable construction timeframe	– Shorter construction duration
Implement within a reasonable construction cost	– Lower construction cost

Table 2-3:
Brooklyn Streetcar Evaluation Criteria

GOAL/OBJECTIVE	EVALUATION CRITERIA
Avoid conflicts with existing and proposed infrastructure during construction and operation	– MINIMIZES INFRASTRUCTURE CONFLICTS
Avoid or minimize utility relocation	– MINIMIZES UTILITY CONFLICTS – MAINTAIN ACCESS TO UTILITIES

3.0 FEASIBILITY CONSIDERATIONS

This section describes general streetcar feasibility considerations typical of a streetcar operating in an urban environment, which will be considered for the proposed Brooklyn Streetcar. These general considerations include the geometric constraints, or physical conditions necessary to provide reasonable operations (i.e. width, height, slope, grade, weight, and existing utilities). These general considerations were derived from the Case Study Report as well as research into systems from Charlotte, North Carolina; Philadelphia, Pennsylvania; Portland, Oregon; and Seattle, Washington.

In addition to a discussion of general feasibility considerations, this section describes the applicability to streetcar feasibility within the Study Area. This approach identifies specific areas of concern in the Study Area and provides an assessment of the potential future streetcar alignment options. Additional analyses to examine these feasibility considerations will be conducted as part of the Brooklyn Streetcar Feasibility Study, and will be reported in the Brooklyn Streetcar Feasibility Study – Feasibility Report.

Specifically, this section will describe the following feasibility considerations:

- Horizontal alignment and curvature
- Grades
- Station platforms
- Vertical clearance
- Roadway cross slopes
- Right-of-way
- Structural operations
- Traffic operation / signals
- Bicycle integration
- Utilities
- Track structure / pavement reconstruction

3.1 Horizontal Alignment and Curvature

Horizontal alignment for a streetcar is primarily concerned with the horizontal clearances to the right and left of the vehicle. Unlike a rubber-tired vehicle, streetcars cannot shift their position laterally within the street. Moreover, since streetcars operate in the same travel lanes as other vehicles, consideration must be given to the available clearances for parked cars and vehicles in adjacent lanes (both in the same direction and on-coming). Adequate clearance must be provided for the horizontal envelope of the streetcars themselves, and this becomes particularly critical at curves.

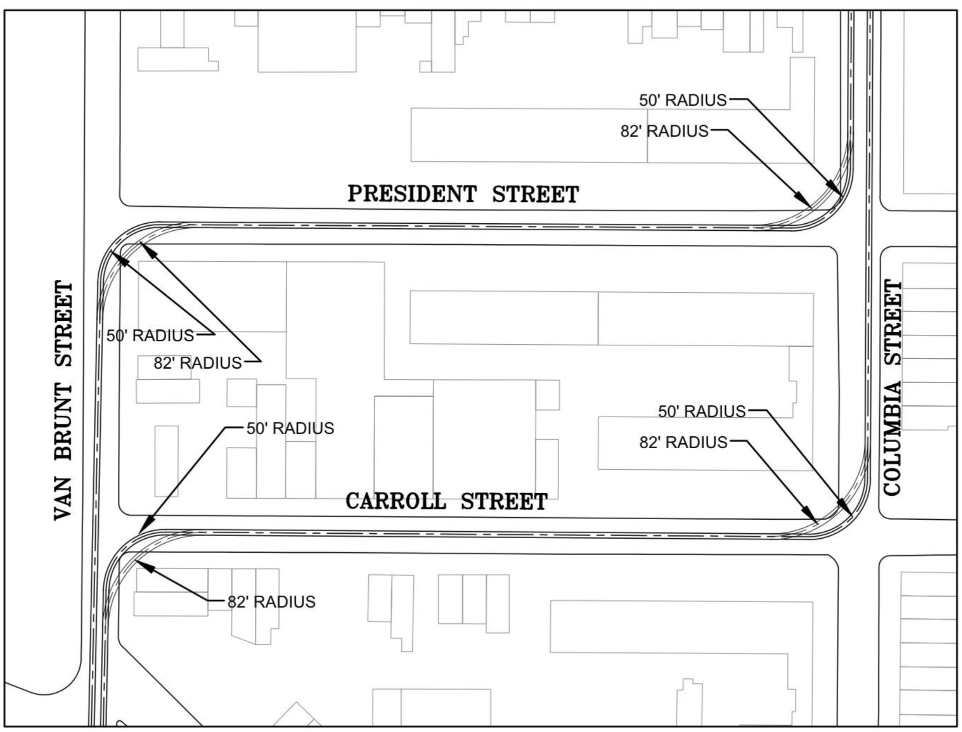
A typical streetcar width is nine feet, and the minimum lateral clearance for a streetcar running adjacent to a parking lane includes an eight foot wide parking lane and a total of 15 feet from the curb line to the center of the track. In locations where there is a likelihood of winter snow conditions, a wider parking lane (11 feet) is desired to account for snow piling conditions. Generally, 12 feet (center-to-center) spacing is recommended for adjacent tracks, although some vehicle types require less clearance. The design of the lane widths to accommodate both street traffic and streetcars is discussed in a later section of this technical memorandum.

Horizontal curvature for streetcar operations is primarily a function of the type of vehicle utilized on the system. The industry standard[1] for the minimum desired horizontal radius for streetcar tracks is 82 feet. However, depending on the vehicle type being utilized, the radius can be reduced to as little as 50 feet to accommodate specific field conditions. Heritage vehicle types are able to negotiate tighter turning radii than those of the modern streetcar vehicles. Specifically, Philadelphia's Route 15 Trolley is in operation with radii as low as 50 feet.

In addition, horizontal curvature is related to the required speeds. At the low operating speeds typically found in mixed traffic service, the radius of the curve is a function of the ability of the vehicle's truck to pivot without encountering physical obstruction in the drive mechanism or car body. On tangent sections (straight track), a curve radius of 600 feet is required to achieve operation speeds of 25 miles per hour.

Based on preliminary investigation in the Study Area, the minimum desired horizontal radius of 82 feet would be difficult to achieve in many locations, as the track would infringe on existing sidewalks, as shown in Figure 3-1 or buildings, as shown in Figure 3-2. For these locations, a turning radius of 50 feet or 60 feet may be necessary, also shown in Figures 3-1 and 3-2.

Figure 3-1: Horizontal Curvature (82 feet versus 50 feet)



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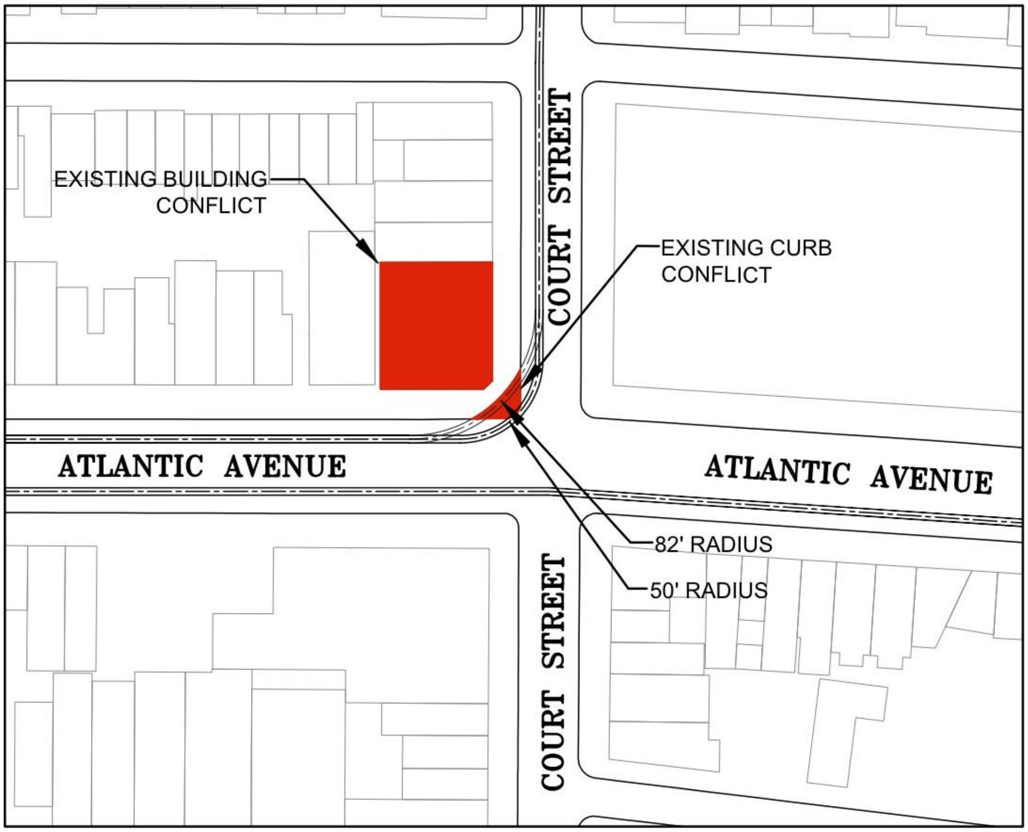
[1] TCRP Report 57 – Track Design Handbook for Light Rail Transit

Figure 3-2: Curb and Potential Building Conflict at Atlantic Avenue and Court Street



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Specifically, the following locations have been identified as needing radii smaller than 82 feet:

- Atlantic Avenue at Court Street – Curb and Potential Building Conflict (Northeast Corner)
- Atlantic Avenue at Columbia Street – Curb and Potential Abutment Conflict (Southwest Corner)
- Columbia Street at President Street – Curb Conflict (Northeast Corner)
- Columbia Street at Carroll Street – Curb Conflict (Northeast Corner)
- President Street at Van Brunt Street – Curb Conflict and Potential Building Conflict (Southwest Corner)
- Carroll Street at Van Brunt Street – Curb Conflict and Potential Building Conflict (Southwest Corner)
- Van Brunt Street at Beard Street – Curb Conflict and Potential Building Conflict (Northeast Corner)
- Beard Street at Otsego Street – Curb Conflict and Potential Building Conflict (Northeast Corner)
- Clinton Street at Mill Street – Curb Conflict and Potential Building Conflict (Southwest Corner)
- Mill Street and West 9th Street at Gowanus Expressway – Conflict with Existing Viaduct Columns

- Court Street at West 9th Street – Curb Conflict (Northeast Corner)
- Garnet Street at Smith Street – Curb Conflict and Potential Building Conflict (Southwest Corner)

At many of the intersections listed above, comprehensive intersection reconstruction could be required to allow for the required streetcar turning radii. Moreover, in some cases reconfiguration of access to a building could be required. For example, there are several options for the potential alignment to travel between Columbia Street and Van Brunt Street (including Sackett Street, Union Street, and Summit Street), as previously shown in Figure 2-7 (page 2-17). Any of these options would require difficult turns due to the narrowness of the streets and the small existing corner radii. In order to make this turn, one or two corner on-street parking spaces would have to be removed. Similarly, the turns to and from Lorraine Street (if this alignment option is selected) would require on-street parking to be removed in order to make the turns feasible.

3.2 Grades

Although the absolute maximum allowable grade is vehicle dependent, and can range as high as nine percent, the desirable maximum grade for streetcar vehicles is five percent. During the fall (with wet leaves) and winter (with snow and ice) grades exceeding five percent can cause severe upgrade slippage, and are therefore generally avoided.

Elevation data obtained from the Department of Information Technology and Telecommunication (DoITT) was used to perform a basic analysis of the slope along the potential alignment options. The highest grades were calculated along Atlantic Avenue between Columbia Street and Henry Street. In these areas the grade is approximately four percent. Therefore, based on this preliminary analysis, there are no grade issues identified. Figure 3-3 shows the general elevation within the Study Area.

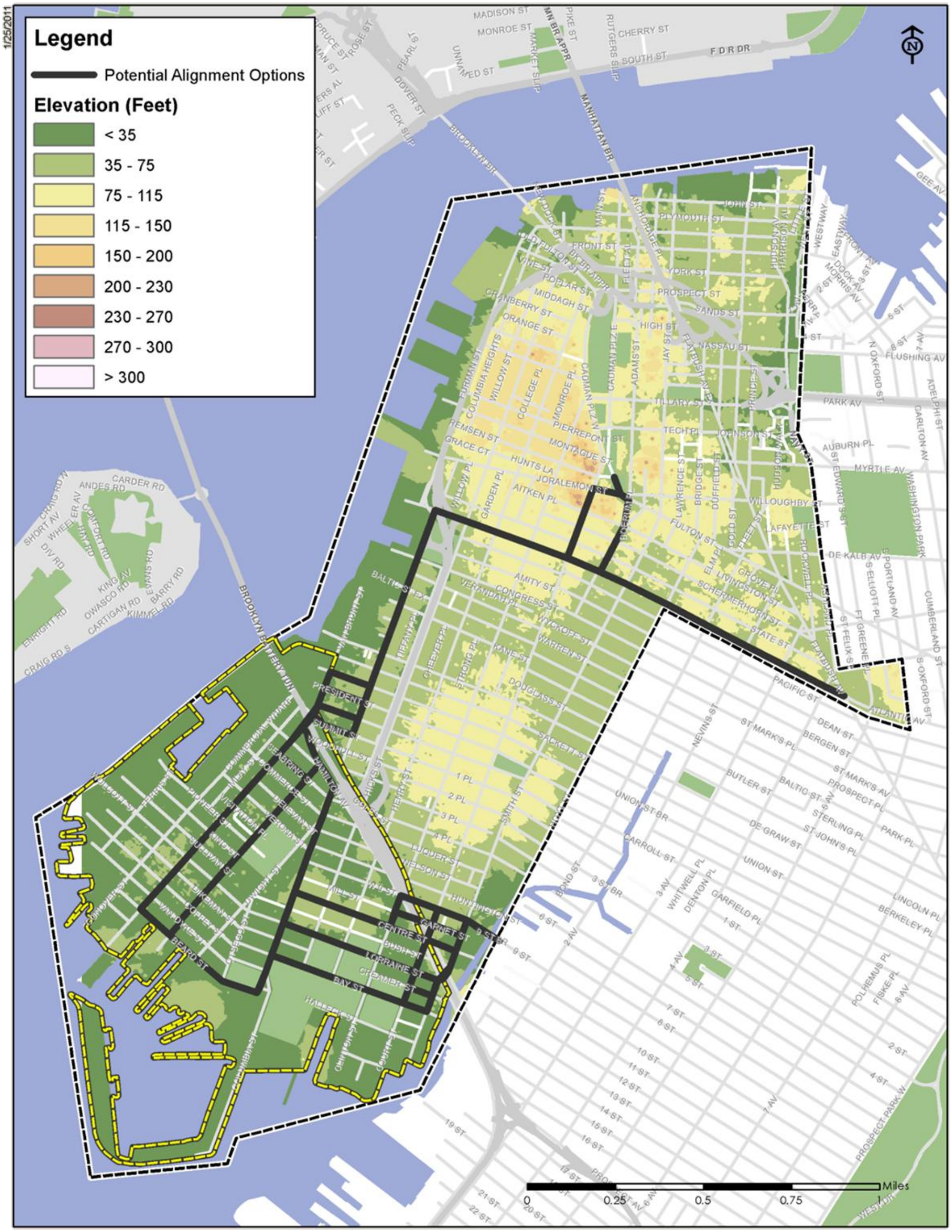
3.3 Station Platforms

The track alignment at the platform should be tangent with less than a two percent grade. Assuming a typical modern streetcar vehicle, the length of the platform should be between forty and sixty feet in order to provide platform access to all vehicle doors. In addition, the platform is treated as an extension of the curb and sidewalk at intersections with stops. At a minimum, the width of the platform should be ten to 12 feet to allow for good pedestrian circulation.

The typical curb height at stations is between ten and 14 inches, and is dependent to some extent on the vehicle. If the vehicle is not capable of self-leveling, a bridge plate is necessary. The horizontal clearance, between the centerline of the track and the platform edge, should be approximately four feet, and is also dependent on vehicle type.

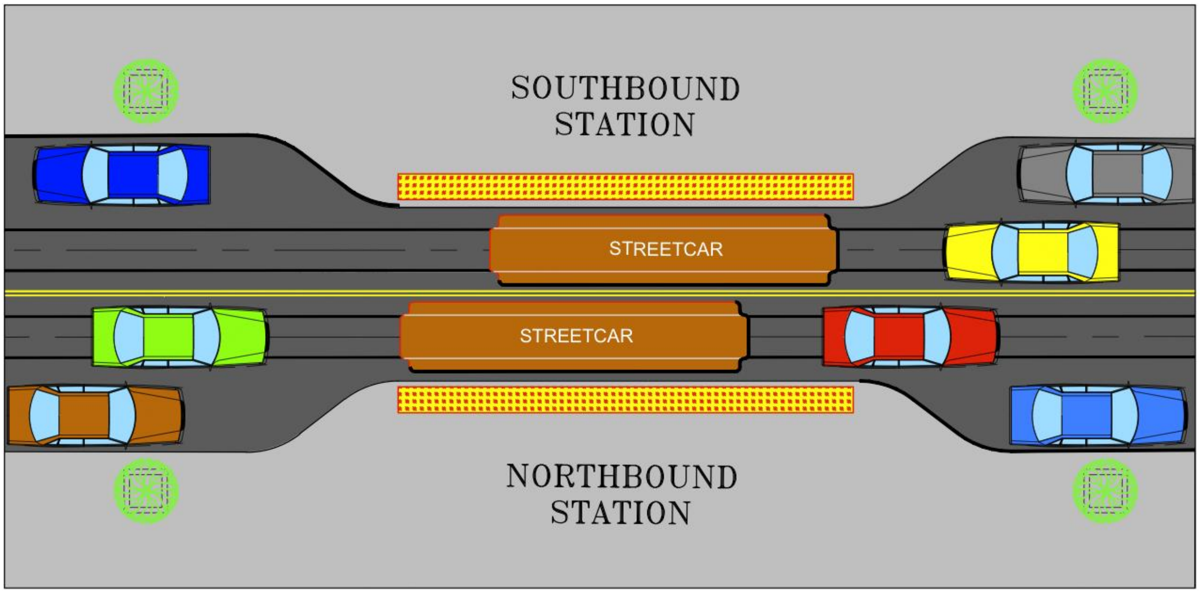
Americans with Disabilities Act (ADA) access and grade requirements must be complied with for all new construction. ADA provisions can be met on historic vehicles through a variety of retrofits; however, ADA compliance is not required. Nonetheless, consideration must be given to the type of service being provided, if historic equipment is utilized.

Figure 3-3: Elevation in Study Area



Because of the grade differential between the existing standard sidewalk and the desired level platform boarding, sidewalk reconstruction and grading work would be required at each stop. The design concept being examined includes the utilization of a bulb out from the existing sidewalk and curb line into the existing on-street parking lane to allow for platform boarding, as shown in Figure 3-4. This would typically eliminate three or four on-street parking spaces at each stop, in each direction.

Figure 3-4: Typical Streetcar Stop



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3.4 Vehicle Clearance

The minimum vertical clearance from the top of the rail to power supply wire is 13 feet, and the maximum height is 21 feet. Vertical clearance less than 18 feet requires the streetcar to be in an exclusive (no other vehicles) lane, unless a variance from the National Electrical Safety code (NESC) is obtained.

For the alignment under consideration, there is one location where the vertical clearance is a concern. This is where Atlantic Avenue crosses under the Brooklyn-Queens Expressway, as shown in Figure 3-5. The clearance is expected to be, at its lowest, between 14 feet 2 inches and 15 feet and 6 inches, on the south side of the structure. This is less than the 18-foot minimum clearance, so a variance would be required. Alternatively the streetcar could be routed under the highest point of the structure, in the middle of Atlantic Avenue. While this would eliminate the vertical clearance issue, it would require additional intersection signal modification to accommodate the left turn onto Columbia Street (for southbound streetcars) and the through movement along Atlantic Avenue (for northbound streetcars), as described in section 3.9.

Figure 3-5: Vertical Clearance on Atlantic Avenue under the Brooklyn-Queens Expressway

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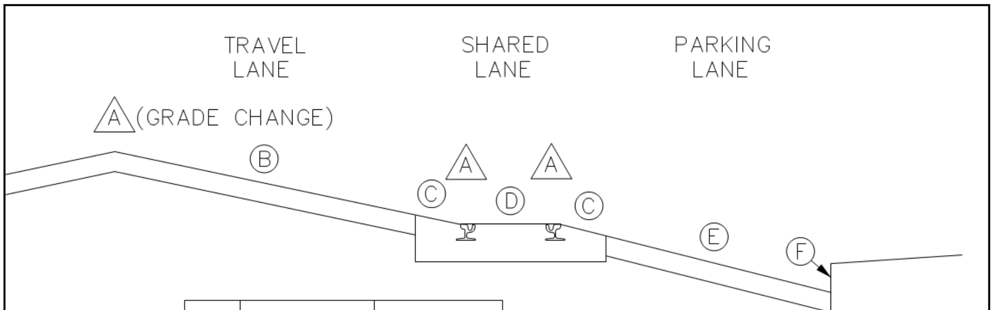
3.5 Roadway Cross Slope

Track slabs are designed to provide a flat (zero percent) slope between the rails. Any slope greater than zero percent is undesirable and can result in uneven rail and wheel wear. In typical roadway construction, the roadway is pitched downward from the centerline of the road toward the gutter to facilitate drainage. This cross section, known as crowning, would create an uneven grade between the rails, with the outside rail being lower than the inside rail. This is undesirable on straight sections of track, but is especially undesirable on a curved section of track, where the crown can produce a backward, or negative superelevation. (Superelevation is the tilting of the trackbed required to help offset centrifugal forces as the streetcar maneuvers around a curve – also defined as the difference in height of the inner and outer rail of the trackbed.)

A level streetcar track slab should be used for all tangent track, except in highly restrictive grading situations where some cross slope could be required to accommodate existing roadway cross slopes. A slight cross slope could be introduced to reduce pavement reconstruction or drainage impacts, but a better solution is to provide a zero percent cross slope between rails and to accommodate the overall cross slope by pitching the portions of the streetcar lane outside the rails between 0 and 5 percent.

Although detailed grading is not generally undertaken until final design, the above method for grading the roadway while maintaining the level track is illustrated in Figure 3-6. This track design attempts to limit roadway reconstruction to only the track slab associated streetcar travel lane. Incidental construction could be required to accommodate relocated utilities. In cases where the track is adjacent to the curb, the rail closest to the curb would be approximately 2.5 feet from the face of the curb. The area between the rail and the face of the curb is then sloped as a gutter to carry water to the nearest inlet.

Figure 3-6: Roadway Cross Section



	Desirable	Maximum
A	3%	5% (2–3% @ Cross Streets)
B	2%	5%
C	2–4%	4.5%
D	0%	1–2%
E	4–6%	7%
F	6”	4” (Curb Exposure)

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3.6 Right-of-Way

The minimum desired lane width for a streetcar track is 11 feet, which accommodates a typical nine-foot wide streetcar and a reasonable separation to adjacent travel lanes, parking, or other streetcar lanes. Adjacent parking lanes should be a minimum of eight feet in width. However, experience in areas where snow can be present, indicates that wider parking lanes (up to 11 feet wide) are preferable to accommodate snow piles. Issues arise in Philadelphia, where parking lanes are less than 11 feet wide, as described in the Case Study Report. Adjacent travel lanes should not be less than 11 feet in width to avoid “crowding” of ambient traffic next to the moving streetcar. In addition, streetcar rails should be placed off-center in the streetcar lane to keep the rails out of the vehicle wheel paths.

Using the above guidelines, the minimum typical cross section to accommodate two-way vehicular and streetcar traffic along with parking on each side is 38 feet, as shown Figure 3-7. (To accommodate 11-foot parking lanes, 44 feet would be desirable). Many of the streets along the potential alignment options are less than forty feet in width, curb to curb, and serve multiple users (i.e. moving and parked vehicles and cyclists). Streets less than 38 feet in width would require the removal of parking from one side, unless the sidewalk areas can be reconfigured to allow the road to be widened to 38 feet. During a preliminary investigation, some of the sidewalks along the potential alignment options have adequate width, and would allow for future reconfiguration.

Figure 3-7: Typical 38-Foot Right-of-Way along Van Brunt

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A 38-foot width is attainable on all of the alignment options at this point with the exception of Columbia Street between Degraw Avenue and Carroll Street. Based on the GIS data and field observation, the road in this area narrows to as little as 35 feet. In order to use this section as a bi-directional double track area, on-street parking or the sidewalk width would need to be modified. In addition, there is an additional alignment option to extend the couplet running mode between Columbia and Van Brunt Streets by traveling down Degraw Avenue to Van Brunt Street, and returning on Carroll Street.

The alignment options developed for this phase of the feasibility study also considered minimal roadway reconstruction in order to run the streetcar service. Minimal roadway excavation and shallow slab construction would be preferable to run a streetcar in the existing streets. However, some intersections would require additional civil reconstruction due to the cornering and clearance envelope of the streetcar. Moreover, some Red Hook streets would require more extensive reconstruction due to the existing street material, as shown in Figure 3-8. The alignment option on Beard Street would be considered full roadway reconstruction, since the existing road is cobblestone and would require extensive reconstruction and grading in order to build the track slab and running rail.

Figure 3-8: Typical Cobblestone Street in Red Hook

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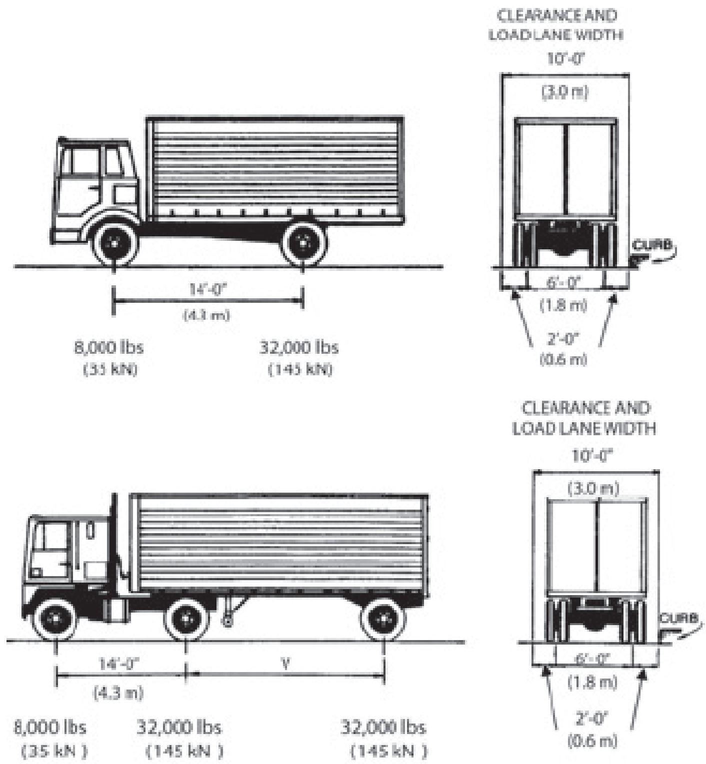
3.7 Structural Loading

Typical streetcar loading is similar to HS20 truck loading, as shown in Figure 3-9; and therefore, poses no special issue or concern in applications on City streets. Heritage vehicles, if selected for a future Brooklyn streetcar, are typically lighter than modern streetcars. During the design process, once the alignment, vehicle type, and other design considerations are determined, a structural engineer would evaluate all structures within the influence of the streetcar.

Figure 3-9: Typical H20 and HS20 Truck Loading



Sketches illustrate AASHTO-approved live loading specifications for standard H20 and HS20 trucks
AASHTO Standard Specifications for Highway Bridges

3.8 Traffic Operations / Signals

A minimum clearance of three feet and eight inches from the streetcar wire to any part of a traffic signal/mast arm or similar structure is required for Occupational Safety and Health Administration (OSHA) certified workers. If non-certified workers are responsible for maintaining lights, signals, and heads, a minimum of ten feet clearance is required. The streetcar design process should coordinate with local agencies and maintenance departments to establish trolley wire clearances. It is likely that some traffic signal equipment would have to be relocated in order to accommodate the overhead streetcar wires.

Streetcar operation is flexible and is typically similar to other vehicles in shared lanes using line of sight. As such, no additional traffic signal control is necessary. However, in certain cases, lane arrangements and geometric constraints would require special traffic signal phasing to accommodate the streetcar movements. One such movement occurs when a streetcar must turn left from the right lane at an intersection, crossing through and/or left turning traffic. This is generally handled with an exclusive signal phase, or an exclusive streetcar lane, also known as "queue jump" phasing.

Additionally, many agencies introduce transit priority movements through detection of the streetcar and the priority service of the streetcar phase, either through a pre-emption system or through a multi-phase actuated signal system. This type of priority phasing could be utilized at any of the signalized intersections throughout the route to facilitate streetcar operations. The following intersections have been identified as probable locations where signal modifications would be necessary:

- At Atlantic Avenue and Boerum Place vehicles would have to turn left from the right hand lane. A queue jump would be necessary at this intersection, and the left turn phasing would have to be made protected.

- Signal modification would be necessary where the potential alignment turns left from Atlantic Avenue to Columbia Street. Due to the geometrics of the left turn and horizontal curvature, the streetcar may need to shift into a wider left lane in order to negotiate the turn onto Columbia Street. This move would require dedicated signal and turning movements, specifically for the streetcar.

- At Boerum Place and Joralemon Street, vehicles would have to turn left from the right hand lane. A queue jump would be necessary at this intersection, and the left turn phasing would have to be made protected.

- Depending on vertical clearance, the streetcar may have to move to the center of Atlantic Avenue under the Brooklyn-Queens Expressway to cross under at the highest point. This would require intersection signal modifications to make the left turn onto Columbia Street (for southbound streetcars) and the through movement (for northbound streetcars). (Vertical clearance is further discussed in Section 3.4.)

- Crossing under the Gowanus Expressway would require signal modification where the potential alignment crosses Hamilton Avenue (at Mill Street and West 9th Street). This is due to the alignment of the streetcar through the columns that support the Gowanus Expressway above Hamilton Avenue. Currently no signal exists here as there is no vehicular crossing.

- An additional signal phase would likely be necessary at the Smith Street and 9th Street intersection in order to handle the streetcar traffic exiting the new terminal at this location.

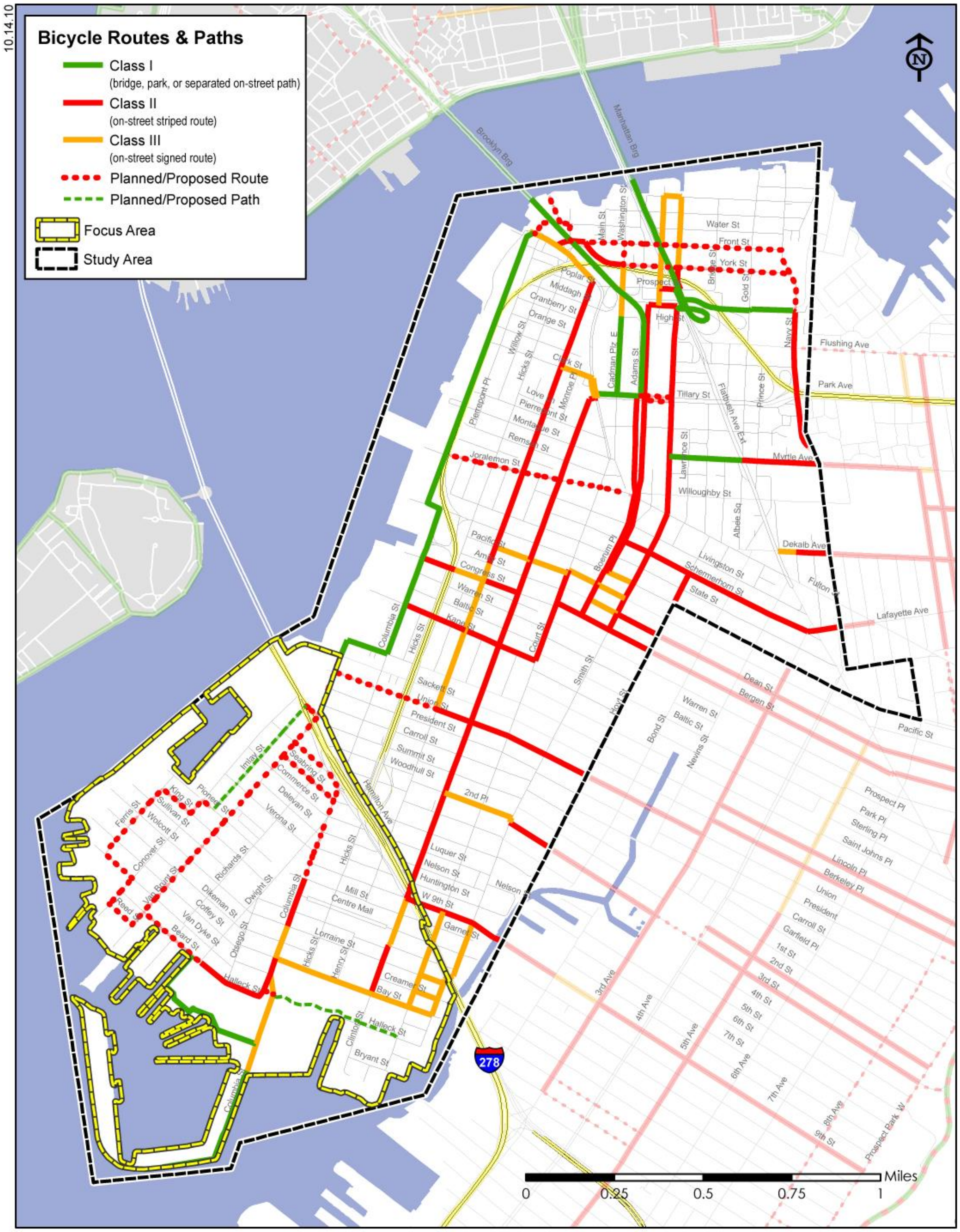
- If the route through the Centre Mall is chosen, it may be desirable to install new traffic signals at the intersections with Clinton Street and Columbia Street.

3.9 Bicycle Integration

The primary issues for bicyclist-streetcar interaction are the flange gap and angle of crossing and right running tracks. When a bicyclist is required to cross the tracks at less than a 60 degree angle, the track “catches” the wheel and the bicyclist may be thrown from their bicycle. This situation is of concern at intersections, especially where bike routes are crossing the streetcar alignment. In addition, right-running tracks present a problem, when a bicyclist riding in the right lane chooses to cross the tracks at an angle less than 60 degrees. This problem is also present at intersections and station stops.

Figure 3-10 shows the designated bike routes and lanes within the Focus Area and Study Area. As reported in the Existing Conditions Report, bicycle routes crisscross the Study Area. In the Focus Area, east-west, Class II bike routes or Class III bike paths are provided along Bay Street, Creamer Street, Lorraine Street, and 9th Street. The Class II bike route on West 9th Street could be a potential conflict with a future Brooklyn streetcar, particularly at the streetcar station stop locations. To integrate these two modes, the bike route could be relocated around the stop, taking some of the sidewalk space.

Figure 3-10: Bicycle Routes and Paths



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A future streetcar would integrate with the separated bicycle path along Columbia Street, as shown in Figure 3-11. However, a potential bicycle conflict would occur when the dedicated path converts to sharrows (or shared-lane marking, as shown in Figure 3-12) along the south section of Columbia Street, between Halleck Street and Creamer Street. In order to integrate a future streetcar with the existing bicycle use along this alignment, the on-street parking lane could be removed from Bay Street to Lorraine Street, as shown in Figure 3-13. (Sharrows shown in green.)

Figure 3-11: Bicycle Integration

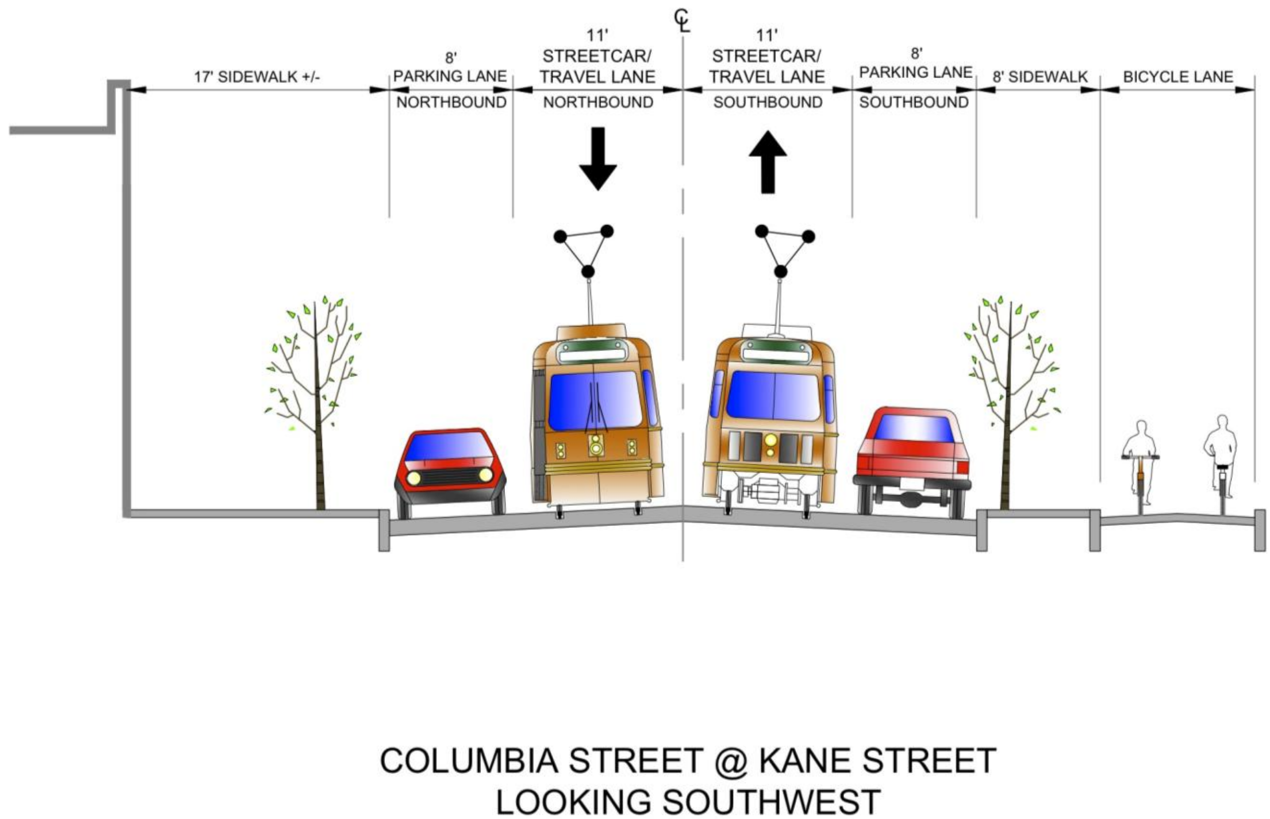

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Figure 3-12: Typical Shared-lane Marking (Sharrow) along Bay Street

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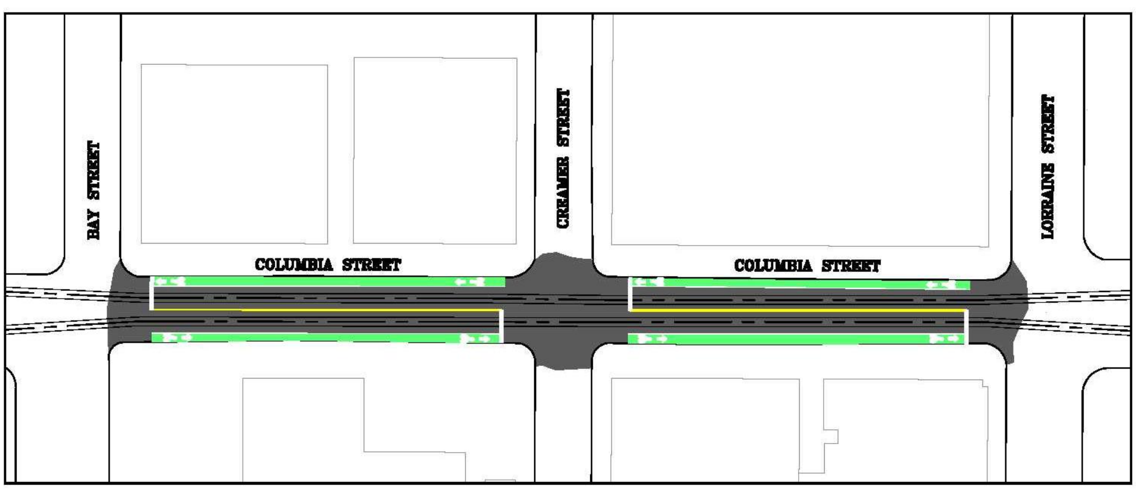
Figure 3-13: Bicycle Integration along Columbia Street



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As part of the New York City Bicycle Master Plan, new bike paths are planned in the Focus Area. Of these, the Class II bike route planned for Van Brunt Street would be a potential conflict with a future Brooklyn streetcar. Both lanes of on-street parking would need to be removed to introduce a Class II bike lane. Alternatively, the proposed Class II bike route could be rerouted to another street (i.e. Richards Street). Based on preliminary investigation of Van Brunt's street width, the latter option would be recommended, as a Class II bike lane would be difficult to integrate into the existing traffic pattern (even without a future streetcar).

3.10 Utilities

Utility clearance requirements should be established with input from the local agencies and utility companies during the early stages of design. For new construction, a utility-free zone within nine to twenty feet from the track centerline to any parallel utility is considered to be ideal. However, in most instances of construction in existing streets, the need to revise infrastructure is related to the functional needs of the individual utility companies and the municipalities involved. As discussed in the Case Study Report, in both Portland and Seattle, utility coordination was critical to successful design and on-going operations. In both cases, utility conflicts significantly increased the cost of the project.

There are several types of utility conflicts that should be resolved during the design stage of a future Brooklyn streetcar. These include:

- Parallel utility conflicts, where utilities may be too shallow to permit them to stay in place, or where the utility may be restricted due to the need to operate under the streetcar line;
- Crossings (such as water), which are typically sleeved, or the pipe is replaced with another, non-conductive material; and
- Surface conflicts where access structures, manholes, valves, etc. are in physical conflict with the streetcar tracks.

A preliminary analysis of major underground utility impacts within the potential alignments was performed based on data received from three adjacent projects within the Study Area to provide a representative sample of potential utility concerns, as well as other available sources for utility information, including:

DOWNTOWN BROOKLYN TRAFFIC CALMING

Drawings were provided showing traffic calming features at certain intersections within the project area along Atlantic Avenue. These drawings indicate existing geometric information and underground utility information for the Atlantic Avenue corridor of the potential alignment.

RECONSTRUCTION OF COLUMBIA STREET (PHASE I)

Drawings were provided from a new water main installation and street reconstruction of Columbia Street in the northwestern quadrant of the Study Area. These drawings indicate existing geometric information and underground utility information for the Columbia Street corridor of the potential alignment.

RECONSTRUCTION OF COLUMBIA STREET AREA (PHASE II)

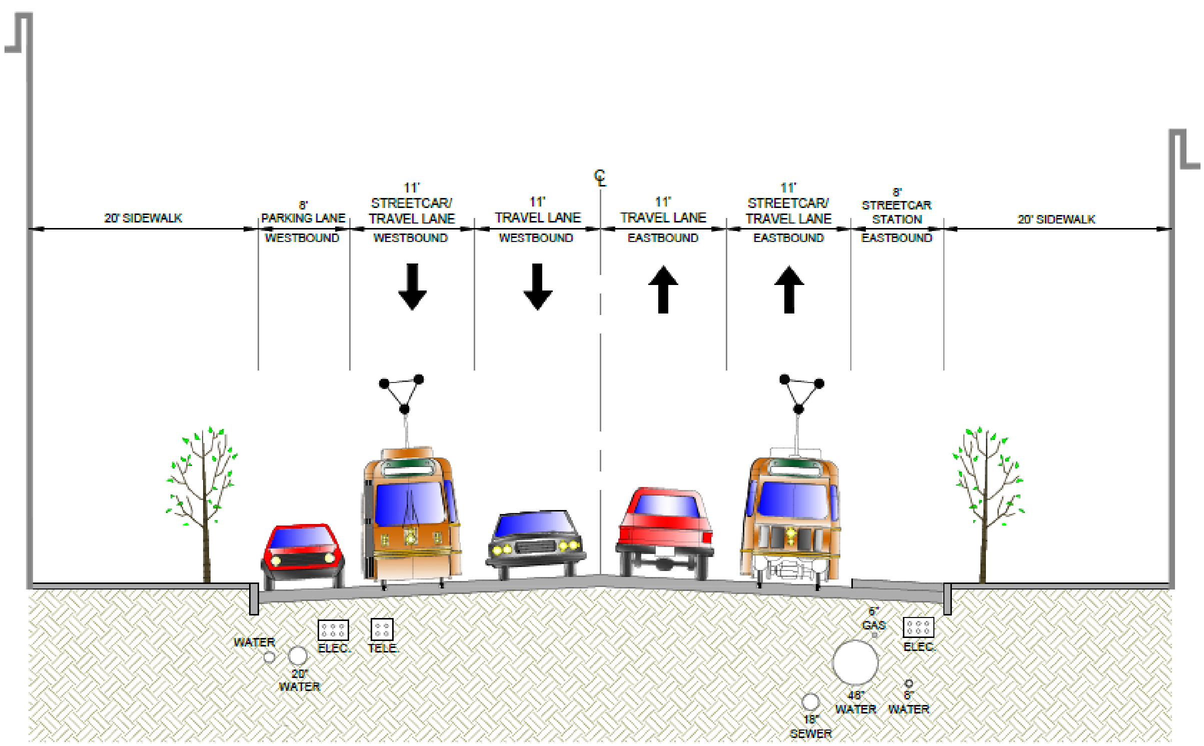
Drawings were provided from a new water main installation and street reconstruction of Van Brunt Street and Richards Street in the southwestern quadrant of the Study Area. These drawings indicate existing geometric information and underground utility information for the Van Brunt Street and Richards Street corridor of the alignment.

OTHER AREAS

Additional underground utility information was collected from the New York City Department of Environmental Protection (NYCDEP) sewer records for the rest of the Study Area. No private utility information was obtained at this early feasibility study phase.

The streetcar construction would be completed using a shallow construction technique that minimizes disruption to the underlying roadbed and utilities. However, at this stage of the feasibility study, conflicts are considered to occur whenever shallow utilities cross the line or run parallel to it, or when large utilities run parallel. Based on the available information previously discussed, a discussion of probable utility impacts at two representative locations is presented below. The cross-sections in Figures 3-14 and 3-15 show the location of existing utilities in relation to the potential streetcar trackbed.

Figure 3-14: Typical Cross Section along Atlantic Avenue (at Clinton Street)



Not to scale
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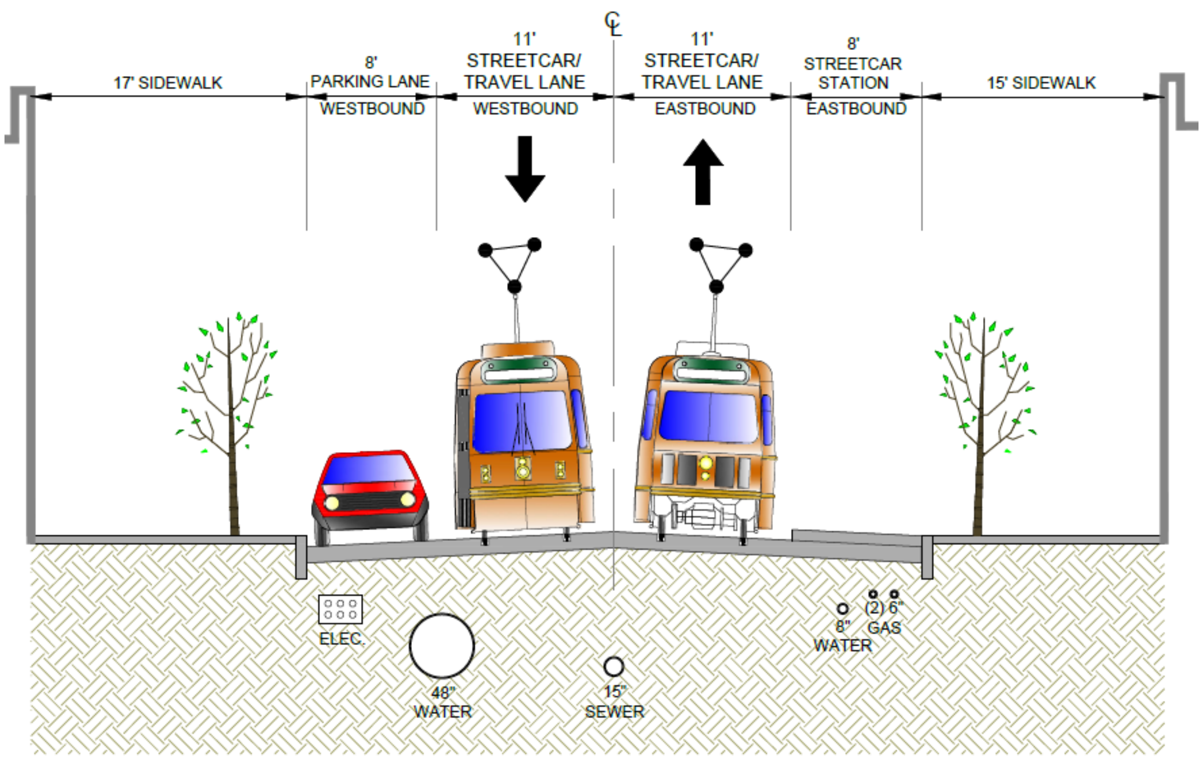
Atlantic Avenue

Atlantic Avenue is sixty feet wide, with two travel lanes in each direction and parking on both sides of the street. The proposed streetcar alignment would run along the rightmost travel lane in each direction. This would allow the parking lane to be maintained except in areas where the sidewalk is bumped out for station stops. According to the records obtained for the Brooklyn Streetcar Feasibility Study, most of the major underground infrastructure along the Atlantic Avenue corridor is below the rightmost travel lane and parking lane, which is in conflict with the proposed streetcar location. It may therefore be necessary to relocate some of the utilities, as indicated in Figure 3-14. (Utilities shown here are not to scale, and the depths shown are estimates based on prior experience.)

Key concerns include an existing 48-inch water main, which runs just below the streetcar track alignment for a major portion of the route, as well as electrical and telephone duct banks, which are shallow and just below the road. While the entire duct bank system may not have to be relocated, most manholes and access vaults would need to be reconstructed out of the streetcar track alignment.

Figure 3-15 Typical Cross Section along Van Brunt Street (at Hamilton Avenue)



Not to scale
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Van Brunt Street

As shown in Figure 3-15, Van Brunt Street is 38 feet wide, with a single travel lane in each direction and parking on both sides of the street. The streetcar tracks would be placed within the travel lane, adjacent to the parking lane, which would also be utilized for station stops at bump outs in the sidewalk. Utility concerns in this area include a 48-inch water main running parallel to the southbound track alignment. According to the information provided, there are no shallow private utilities along the Van Brunt corridor that would need to be relocated.

ADDITIONAL UNKNOWN CONFLICTS

Because of the preliminary nature of this feasibility investigation, there is a possibility that there are additional utilities that may be in conflict with the proposed streetcar alignment options. However, they have not yet been specifically identified. For example, based on planning and engineering experience, it is anticipated that a number of utilities are located under the Gowanus Expressway. These could be impacted by the proposed streetcar alignment. Detailed investigations would be required to identify all potential conflicts, and an in-depth discussion would be required with City officials and utility company representatives to determine the best way to deal with these potential conflicts.

Another conflict that was not investigated at this early feasibility study stage is the presence of any building vaults that may exist below the sidewalk or in the street along the alignment options. Further study would be necessary to determine if any vaults exist attached to building along the route, and the extent of the impact they would have with the roadway and sidewalk reconstruction.

3.11 Track Structure / Pavement Reconstruction

Many track structure designs have been implemented in the various light rail transit or streetcar systems around the country. Embedded girder rail in a concrete track slab is the most common of streetcar systems in shared-use traffic lanes. A typical streetcar track slab is approximately eight feet wide by 12 inches thick, but the design varies depending on various factors (i.e. local soil conditions, pavement design life expectations, and potential utility spanning). The track slab is placed over a compacted base course on an approved subgrade, with the base course thickness varying depending on the pavement design life and bearing capacity of the subgrade.

Pavement reconstruction can be limited to three feet or less on either side of the track slab depending on the existing cross slope and profile of the roadway. This method is currently being used during the construction of Philadelphia’s Route 15 Trolley extension, as shown in Figure 3-16.

Additional reconstruction or grinding/overlay could be required depending on the streetcar alignment and profile, station locations, or other special considerations. In addition to the tangent alignment reconstruction, right angle turning movements would typically require more extensive reconstruction, including sidewalk and portions of the intersection, in order to support the construction of the radius and sidewalk corner impacted by the turning movement.

Figure 3-16: Construction of Philadelphia's Route 15 Trolley Extension

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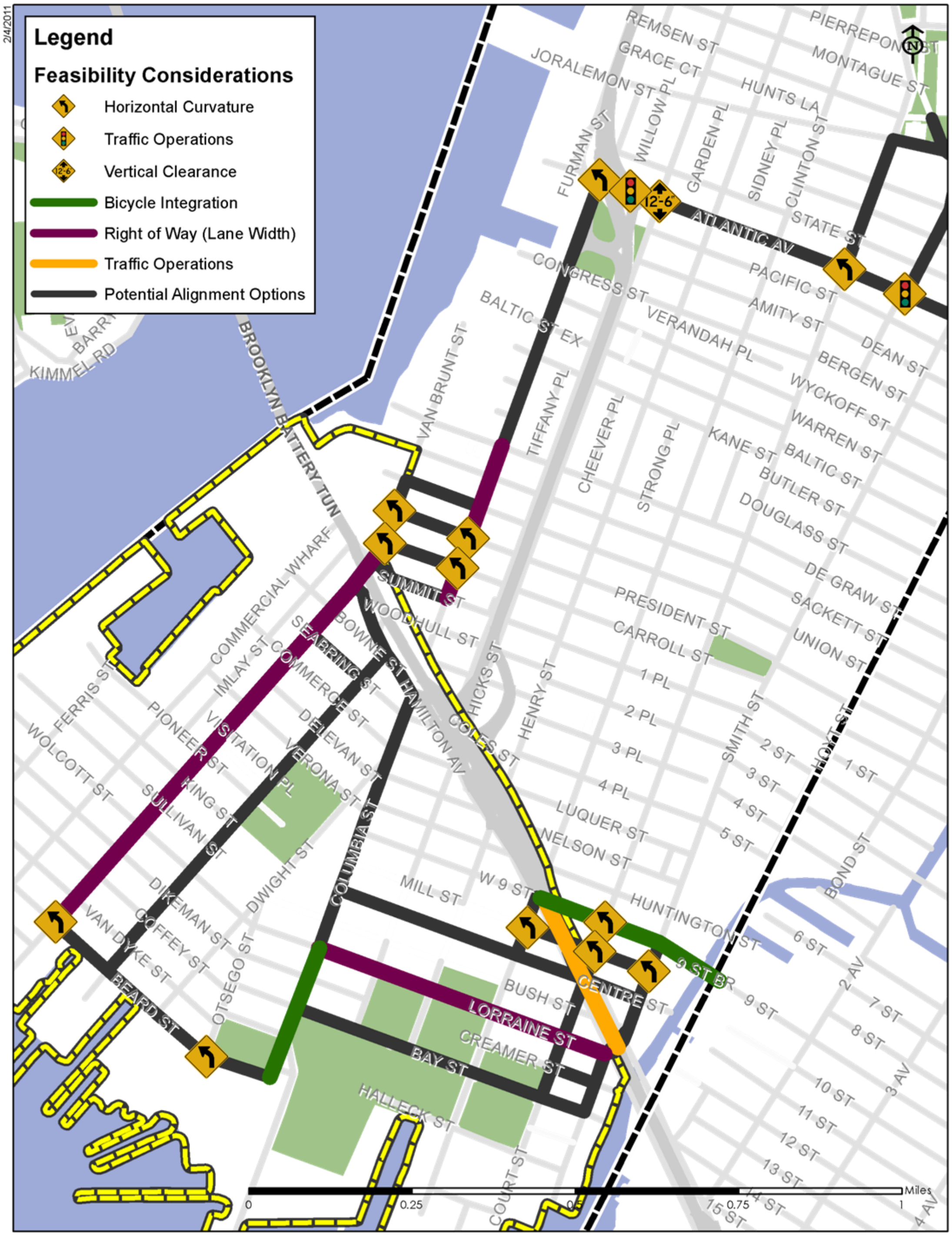
4.0 CONCLUSION AND NEXT STEPS

Based on preliminary investigations, Figure 4-1 identifies the areas of potential concern, including horizontal and vertical clearance issues and traffic operations impacts that need to be considered when evaluating the feasibility of a Brooklyn streetcar system. Additional analyses will be conducted and reported in the Brooklyn Streetcar Feasibility Study – Feasibility Report.

Figure 4-1: Feasibility Considerations



NYCDOT - BROOKLYN STREETCAR FEASIBILITY STUDY

Feasibility Considerations